4.0 CONCEPTUAL SITE MODEL

This section presents the known primary sources of contamination, transport mechanisms, and potential exposure pathways to human and ecological receptors.

The CSM summarizes the primary basis for the sampling activities planned for this investigation.

Information used in the development of the CSM includes the following:

- Historical sediment chemistry data
- Historical sediment investigation observations
- Hydraulic modeling of river flows immediately upstream of the dam complex
- Principles of physical and chemical transport
- Construction site history
- Biological characterization

4.1 KNOWN AND POTENTIAL SOURCES OF CONTAMINATION

Sources from both in-water placement of debris and runoff from upland areas on Bradford Island have likely impacted sediments in the near shore areas of the island. These sources are summarized below, and depicted on Figures 3-2, and 3-3.

- **In-Water Debris Piles.** Debris, including PCB-containing electrical equipment, was disposed in the nearshore areas north and east of Bradford Island in three piles (Piles #1, #2, and #3). The debris was removed in February 2002. Sediment chemistry samples were collected in Piles #1 and #2 prior to debris removal. Metals, SVOCs, and PCBs were detected in the sediment in the samples collected. Samples have not been collected in Pile #3, although soil samples have been collected immediately upland of this former in-water pile (see bulb slope discussion below).

- **Sandblast Area Sources.** PCB-containing oil was released from an electrical transformer in 1995 near the Sandblast Building on Bradford Island (USACE, 1995). The release was transported to the river via storm drains based on the visual observation of sheen in the river. Sandblast media is presently disposed of south of the Sandblast Building. Sediment samples have been collected from the catch basins as well as immediately adjacent to the outfalls. Metals, SVOCs, and PCBs were detected in the sediment in the samples collected.

- **Landfill Debris.** Debris was disposed of in below surface pits on the eastern end of Bradford Island. The debris has contaminated nearby surface and subsurface soil. Sediment analytical results collected as part of the debris pile investigation may represent impacts from the landfill via overland runoff or groundwater/surface water interaction; however, the results more likely represent impacts from the in-water debris. Metals, PCBs, VOCs, SVOCs, organochlorine pesticides, and petroleum hydrocarbons have been detected in the surface and subsurface soil as well as the groundwater within the landfill footprint.

- **Bulb Slope.** Discarded light bulbs (mostly fluorescent) were discovered upland of Debris Pile #3. Soil samples collected in this area indicate that low levels of lead, mercury and PCBs are present in the surface soils.
- **Bradford Island Dredging.** Sediments were excavated from the south side of Bradford Island during the construction of the new navigation lock located downstream from the sources described above. Contaminated sediments transported by river processes may have impacted these sediments. The dredged sediments were placed as Goose Island.

Potential additional sources of contamination to sediments in the Bonneville Dam Forebay area may include:

- Non-point storm water runoff that may be impacted by miscellaneous operations and activities at the Bonneville Dam complex.
- Potential soil contamination in the former Pistol Range area (currently under investigation).
- Chemical leaching from coated structures within the forebay area primarily treated wood or anti-fouling paints.
- Point and non-point sources in the Columbia River upstream of the Bonneville Dam forebay area.

4.2 CONTAMINANTS OF INTEREST

To choose the analytical suite for this investigation, the detected analytes from the previous investigations of the source areas were summarized based on their presence either in the former piles or near the catch basin outfalls. The data collected during these investigations is discussed in detail in several reports and is summarized below.

- PCBs – Two PCB Aroclors have been detected in the sediment samples: Aroclors 1254 and 1260. The source of the PCBs detected in sediment samples collected from Piles #1 and #2 are likely the result of electrical equipment disposal in these areas (the equipment and all other wastes in the river was removed in March 2002). The source of PCBs detected in the sediment beneath the catch basin outfalls is likely the release of PCB-containing oil from an electrical transformer. Transformers are no longer dissembled at this location.
- Petroleum hydrocarbons – Petroleum hydrocarbons were not detected in sediment samples collected from debris piles. Heavy oil range organics were detected in sandblast drain outfall sediments and are likely the result of the release of transformer oil.
- Pesticides – 4,4’-DDT, 4,4’-DDE, and 4,4’-DDD were detected once each at very low concentrations in Pile #2. The source may be pesticide-contaminated soil in the landfill area, or may be related to ambient concentrations found throughout the Columbia River system.

- Chlorinated herbicides – Herbicides were not detected in sediments.
- Metals – Metals were detected in sediment samples collected from Piles #1 and #2. Sources of these metals may be the debris disposed of offshore. Sandblast grit was also observed in the landfill, which may be transported via overland runoff or groundwater/surface water interaction into near shore sediments. Metal detections are anticipated offshore of the bulb slope, in Pile #3, due to detections of lead and mercury in the soil upland of the Pile #3.

  Metals were also detected in catch basin outfall sediments. The source of metals in the outfall sediment may be the sandblast grit, which was observed on the riprap below the outfall.

  Metals results were compared to literature background concentrations (*Lower Columbia Reconnaissance Survey of the Lower Columbia River*, 1993 and *DEQ background concentrations for freshwater sediment*, 2002) and to concentrations detected in two sediment samples collected by the USACE upstream of the area of potential source impact (Table 4-1). Aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, magnesium, manganese, mercury, silver, thallium, potassium, and vanadium were all detected in the source area in concentrations similar to or below the background concentrations. These metals are not considered PCOIs.

  Metals that exhibiting detections above background concentrations and are considered PCOIs are chromium, cobalt, copper, iron, lead, nickel, selenium, and zinc. Although mercury was not detected above background concentrations it is retained for analysis due to the presence of the mercury-related sources, i.e. mercury vapor lamps.
- SVOCs – SVOC detections were limited to PAHs in the debris pile areas. PAH detections in debris pile two may be a result of the release of oils from electrical debris. SVOC detections in the catch basin outfalls included PAHs, carbazole, dibenzofuran, 3-&4-methylphenol, and bis(2-ethylhexyl)phthalate. The source of the PAHs may be the transformer oil release. Carbazole, dibenzofuran, 3-&4-methylphenol, and bis(2-ethylhexyl)phthalate sources are unknown.
- Butyltins - The source of butlytins in the catch basin outfall sediments may be due to the disposal of sandblast grit upgradient of the catch basin in the vicinity of the sandblast shop.

Detections were then compared to the upstream detections (primarily of metals and SVOCs) to determine if these were from background sources. Table 4-2 provides the summary of the PCOI evaluation.

Based on this analysis, the following classes of chemicals have been identified as PCOIs:

- Polychlorinated Biphenyls
- Diesel and Motor Oil Range Organics (petroleum hydrocarbons)
- Pesticides

- Metals – chromium, cobalt, copper, iron, lead, mercury, nickel, selenium, zinc
- Semivolatile Organic Compounds
- Butyltins

Herbicides were not detected within the source areas, therefore they are not retained as a PCOI. The selection of target chemical classes was not based on a comparison of the concentrations against a human health or ecological health risk screening value. The majority of the sediment samples collected during this investigation will be analyzed for the full PCOI list (full suite) to allow screening to be completed during the risk assessments.

4.3 HYDROLOGY

The Columbia River drains a large portion of the Northwestern United States from its inception in Canada 1,223 miles to the Pacific Ocean. The climate of the Columbia River basin ranges from moist maritime conditions near the Pacific Ocean, to desert conditions in some regions. Peak flows occur as snowmelt leaves the mountain regions, during May and early June. Flow is altered from its natural state by the operations of several federal and non-federal dams. There are over 250 reservoirs and approximately 150 hydroelectric projects in the basin, including 18 mainstem dams on the Columbia and its main tributary, the Snake River (BPA, 2001).

The discharge for this portion of the Columbia ranges from 117,200 cubic feet per second (cfs) to 309,600 cfs (USGS, 2002). The average discharge is 192,106 cfs. This discharge is based on a stream gage that is downstream from The Dalles Dam that has been in operation since 1858. The USGS also collected water quality samples at this station between 1955 and 1978.

Figure 2-1 depicts the dams within the Columbia River basin. All the major dams and reservoirs within the basin are operated in coordination with each other to manage floods, control fish migration, and produce power.

The dams are generally managed to reduce the spring high water flows through storage of excess water in the reservoirs. Stored water is released during the late summer, which generally increases flow above what would occur naturally. The USACE began spilling water for fish at several of its projects in 1977 as a way of improving juvenile fish passage survival. A more comprehensive spill program was initiated at the request of the region in 1989 when Bonneville Power Administration, the fisheries agencies, tribes and others signed a long-term spill agreement (BPA, 2001).

The general operating year for the dams and reservoirs within the basin is divided into three time periods:

- September through December – A fixed reservoir drawdown occurs since a forecasted volume of runoff that will occur in the spring is not yet available. Flows are also managed to enhance the spawning of chum salmon below Bonneville Dam.

- January into Mid March to April – A variable drawdown occurs to meet the forecasted volume of the spring runoff based on snowpack measurements. Water must also be present in April for juvenile fish migration.
- April through August – Refill Season. The reservoirs are managed in an effort to fill the reservoirs and allow fish migration.

At the Bonneville Dam, water is released through the dam spillway (spilled) to aid fish migration between early March and August.

In general, the Columbia River flows west; however, local flow direction and velocity are strongly affected by the above management requirements for the operation of the two powerhouses and the navigation lock. Below the Bonneville Dam, the Columbia River is tidally-influenced.

4.4 CONTAMINANT TRANSPORT FROM UPLAND SOURCES

Site characteristics that influence contaminant transport from known upland sources are described below.

Source: Landfill Debris

<u>Overland transport</u>: North of the landfill the land surface drops steeply, approximately 30 to 35 feet to the Columbia River. The topography east of the landfill also drops steeply to the Columbia River. Surface water drainage at the landfill generally follows the topography as sheet flow, which trends to the north-northwest. Site contaminants in surface soil may be transported by overland runoff to the river.

<u>Groundwater transport</u>: Precipitation that infiltrates the soil at the site may percolate to groundwater. Groundwater at the site flows to the north under both wet season and dry season conditions. Groundwater discharge to surface water occurs as diffuse flow in the high permeability materials in the steep slopes on the northern edge of the island as well as in seeps located in vertical fractures in the underlying low permeability materials. Groundwater may discharge directly to the river or through seepage (observed along the north slop of Bradford Island).

Source: PCB-Containing Oil and Sandblast Grit

<u>Overland transport</u>: The topography north of the sandblast building slopes towards the Columbia River. Surface water drainage in the sandblast building vicinity is typically channeled in one of two ditches ending at two catch basins. Both catch basins contain a ‘sock’ to catch soil that is transported into the catch basins. The socks are replaced at regular intervals. Surface water entering the catch basins drain to the river.

<u>Groundwater transport</u>: Groundwater hydrogeology in the sandblast building area has not been characterized. However, if the groundwater flow is similar to the topography in the area, groundwater from this area flows north toward the river.

4.5 SEDIMENT TRANSPORT

Sediment transport above the dam is affected by the variable flow conditions that may be present. This area is affected by several conditions that affect flow velocity and direction including: time of year, powerhouse operation, spilling, and navigation lock operation. Sediment also has been removed by dredging the south side of Bradford Island and placed to create Goose Island.

4.5.1 Hydraulic Modeling

To assess the effects of the dam and powerhouses on flow direction and velocities, the USACE conducted 3D hydraulic modeling during three scenarios: no spill with low river flow, no spill with a medium river flow, and spill with high river flow. Appendix C contains a memorandum that describes the modeling runs. The model illustrates bottom flow directions and relative velocities under each modeling condition.

<u>No Spill-Low Velocity</u>

This model run (Appendix C, Figure 10) results in a large area of lower velocity water upstream of the spillway. Areas of lower velocity also exist near Goose Island, downstream of Picture Rock, on the south side of Bradford Island, and downstream of the Eagle Creek confluence (less than 0.3 feet/second). Areas of lower velocity are also present in the forebay of the second powerhouse. High relative velocities occur near the eastern tip of Bradford Island (approximately 0.5 feet/ second to 1 feet/ second) and in the first powerhouse forebay (approximately 1 feet per sec to 1.5 feet / second).

<u>No Spill-Medium Velocity</u>

This model run (Appendix C, Figure 7) again results in a large area of lower velocity (less than 0.3 feet/ second) upstream of the spillway, although there is more low velocity area along the north side of the spillway forebay. Similar areas of lower velocity exist when compared to the no spill low velocity scenario, although the velocities are elevated an order of magnitude.

<u>Spill-High Velocity</u>

Areas of lower velocity still exist downstream of picture rock and upstream of the spill way, although these areas are localized and less than 0.4 feet/second (Appendix C, Figure 9). A notable area of low velocity exists near the catch basin outfalls on the north side of Bradford Island. The modeled velocities at the eastern tip of Bradford Island are now as high as 2.8 feet/second.

<u>Modeling Conclusions</u>

Several similarities exist between each of the model runs. For instance, the bottom flow direction as the water enters the forebay area is downstream (west) until a rock outcrop in the middle of the river (Picture Rock). There is a bottom flow direction reversal at this location even under high river flow conditions. This flow reversal results in relatively lower velocities downstream of Picture Rock under all flow conditions. Also present under all flow conditions is a general area of relative lower velocity adjacent to the north side of Bradford Island near the catch basin outfalls.

A large eddy effect occurs during times of no spill in which water enters the forebay, is split into two directions, and directed towards the second powerhouse and the dam. The water flowing towards the dam enters the on the north side, runs south up to Bradford Island, and then back upstream to the eastern tip of Bradford Island. The flow then is to the south and into the first powerhouse forebay. The eddy can be reversed based on how much flow is being directed to each powerhouse.

When spilling occurs, the sediment that is deposited in the lower velocity zones in the dam forebay is likely scoured. However, low velocity areas that are present during all conditions are targeted for sampling (see Section 5.1.2).

Velocities at the tip of Bradford Island are in the range of 1-3 feet/second. Given these velocities, up to sand sized particles (1 millimeter) are expected to erode (Boggs, 1987).

4.5.2 Sediment Characteristics

Diver observations and analysis of sediment grain size within the dam forebay indicate that the sediments primarily consist of sand-sized particles, with pockets of finer-grained materials. Figure 4-1 depicts the sample locations and associated sediment grain size.

Sediment at the former debris piles consists of concentrated areas of fine-grained material located between cobbles and boulders. Sediment from beneath the outfalls and near Goose Island is medium sand, with some other fine grain fraction. The sediment characteristics at the three potential source areas are described below in detail.

- Debris Pile Area - Sediments in the debris pile areas consist mostly of sandy gravel, gravel, and gravelly sand with little or no fines, which represents small pockets of sediment that exist between larger (cobble size) grains and rocks. The lack of fines in this area are probably the result of high velocity flow (scour) as suggested by hydraulic modeling.

  Total organic carbon (TOC) in sediment samples collected in the debris pile areas exhibited low concentrations (below 0.5%). These sediment characteristics (grain size and TOC) normally indicate that organic compounds partition to the solid phase less than if more fines and a higher TOC concentration were detected. However, hydrophobic organic compounds (mostly PCBs and PAHs) have been detected in significant concentrations in sediment samples collected in this location.

- Catch Basin Outfall Area – Sediment in the catch basin outfall area consists mostly of medium sand with some gravel and some silt. The higher percentage of fines in this area may, relative to the debris pile area, be the result of low velocity flow and deposition as indicated by hydraulic modeling (above). TOC concentrations were also greater than those found in the debris pile area (ranging from 0.41 – 2%).

- Goose Island – Goose Island was constructed between 1984 and 1988 from during the construction of the new navigation lock. The island was constructed with high banks and rip-rapped banks. Soils on Goose Island were imported from Bradford Island. Areas of finer grained materials have been observed in this location, although grain-size analysis has not been completed. The TOC concentration for the sediment sample collected at the downstream tip of the island was 0.47%. Hydraulic modeling also indicates that a depositional area may exist at the western tip of Goose Island.

4.5.3 Sediment Transport

The hydraulic conditions and sediment characteristics indicate that former debris pile areas #1 and #2 are scour areas (high velocity). Conversely, former debris Pile #3 and the catch basin outfall area are depositional areas (low velocity) that may be erosional during parts of the year.

Sediment in the Bonneville forebay area may be transported downstream, upstream, or south, depending on spill conditions. Sediments transported from the source areas are anticipated to remain west of river mile 147. Sediments originating from former Piles #1 and #2 may be transported downstream and be deposited east of the spillway, may be transported through the spillway under high spill conditions, or may be transported to depositional areas in the Powerhouse 1 forebay area.

In addition to sediment transport within the forebay area, some Columbia River sediments upstream of the site are transported downstream and under some conditions are deposited into the Bonneville forebay area. Sediment sampled upstream of the eddy effect caused by the dam complex indicate that metals and PAHs are present and may contribute to the impacts observed within the forebay.

During high spill conditions (i.e., spill >150 thousand cubic feet per second [Kcfs]), upstream sediments may be transported through the forebay area and continue downstream. During low spill conditions (i.e., no spill to 150 Kcfs spill), upstream sediments may be deposited in the low velocity areas within the forebay and may cover or mix with areas of sediments originating in the source areas.

The hydraulic modeling indicates that there are several possible depositional areas within the forebay of the spillway that occur under differing hydraulic conditions. The possible depositional areas depicted on the modeling plots as areas of lower relative velocity (blue shaded areas in Appendix C).

The depositional areas can be divided into four main groups: the spillway forebay, Goose Island, the first power house forebay, and the second powerhouse forebay. A description of each depositional area is provided below.

Sediment sampling will be attempted at these depositional areas (see Section 5.1.2).

Spillway Forebay

During no spill conditions a large area upstream of the spillway has been modeled to have low velocities (<0.3 feet/second). During spilling, an area of lower velocity remains on the north side of Bradford Island, near the catch basin outfalls. This area is an intake area for the Auxiliary Water Supply (AWS) that supplies the western lateral of the fish ladder with water. Under certain conditions sediment may be deposited in this area and possibly be entrained in the water used for the fish ladder.

Under all modeled conditions there are several areas downstream of Picture Rock that may be depositional, due to the flow direction reversal effect. Discrete areas that will be sampled downstream of Picture Rock are currently being refined by the USACE, and will be incorporated into the final version of this document.

Goose Island

Under all modeled conditions the upstream and downstream tips of Goose Island may be depositional based on lower relative velocities. However, the upstream tip is outside of the eddy effect, and therefore is not expected to receive sediments from the forebay area.

First Powerhouse Forebay

Four areas within the first powerhouse forebay may be depositional based on the modeling: the south side of Bradford Island, downstream of the confluence with Eagle Creek, the upstream sills for the old and new navigation locks, and the area where the first powerhouse abuts the old navigation lock. The area where the first powerhouse abuts the old navigation lock is also an intake area for AWS-1.

Second Powerhouse Forebay

The north and south shores of the river, immediately upstream of the second powerhouse are modeled as lower relative velocity under all conditions.

4.6 PRELIMINARY RECEPTORS

The potentially complete exposure pathways are divided into human health and ecological receptors below. The conceptual site model is presented in Figures 4-2 and 4-3.

4.6.1 Human Health

Exposure for human receptors is limited in the offshore area of Bradford Island. Recreational use is restricted in the Bonneville forebay area, however recreational fishing does occur both upstream and downstream of Bradford Island. Upstream fishing locations are not anticipated to be impacted by site-related sediment contamination given results of the hydraulic modeling described above. However, recreational fishing does occur downstream of Bradford Island. The recreational fisherman may be exposed to contaminants via ingestion of contaminated aquatic species. In addition, subsistence fishermen may harvest in close proximity to the island; tribal gill nets have been found nearby. The frequency with which subsistence fisherman harvest in this area is currently not known. There are no additional human health exposure pathways. Water in the Columbia River forebay is not known to be used as a drinking water supply.

4.6.2 Ecological

Two types of ecological receptors may be exposed to site-related sediment contaminants: aquatic biota and aquatic-dependent terrestrial biota.

Aquatic Biota

The Lower Columbia River is know to support a large diversity of native resident fish species such as white sturgeon, longnose suckers, minnows, cutthroat trout, whitefish, and a variety of sculpins (Troffe, 1999). White sturgeon and the chiselmouth are restricted in their current distribution and, due to their habitat requirements, are believed to live near Bradford Island.

Anadromous fish species that may be present in the Columbia River in the vicinity of Bradford Island include evolutionarily significant units (ESUs) for seven listed fish: sockeye salmon, Lower Columbia River steelhead, Snake River Basin steelhead, Middle Columbia River basin steelhead, chinook salmon (two species), Lower Columbia River coho salmon.

Introduced fish populations that are popular recreational species are largemouth and smallmouth bass, catfish, yellow perch, and walleye.

Contaminant exposure to aquatic biota include:

- Incidental ingestion, dermal contact, or food web ingestion from surface water contaminants.
- Incidental ingestion, dermal contact, or food web ingestion from sediment contaminants.

Aquatic-Dependent Terrestrial Biota

The bald eagle is the only special-status species that is likely to occur in the upland habitats of Bradford Island. Other non-listed species that may be exposed include aquatic-dependent birds such as cormorants and mammals such as otters.

Contaminant exposure to terrestrial biota includes:

- Incidental ingestion, dermal contact, or food web ingestion from surface water contaminants.
- Incidental ingestion, dermal contact, or food web ingestion from sediment contaminants.

4.7 CONCEPTUAL SITE MODEL UNCERTAINTIES

The following uncertainties exist in the conceptual site model:

- Hydraulic modeling for a spill events with a low or medium river discharge was not produced, although these scenarios are less likely than the modeled scenarios.
- The effect of the filling of the navigation lock on the velocity and flow direction is unknown.

- Historical trends of powerhouse and dam operation on the past transport of sediments within the forebay area.
- The impact of dissolved phase contaminants from upstream sources on sediment in the study area.